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NACA

RESEARCH MEMORANDUM

FLIGHT INVESTIGATION FROM HIGH SUBSONIC TO SUPERSONIC SPEEDS TO DETERMINE THE ZERO-LIFT DRAG OF A TRANSONIC RESEARCH VEHICLE HAVING WINGS OF 45° SWEEPBACK, ASPECT RATIO 4, TAPER RATIO 0.6, AND NACA 65A006 AIRFOIL SECTIONS

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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RESEARCH MEMORANDUM

FLIGHT INVESTIGATION FROM HIGH SUBSONIC TO SUPERSONIC SPEEDS TO DETERMINE THE ZERO-LIFT DRAG OF A TRANSONIC RESEARCH VEHICLE HAVING WINGS OF 45° SWEEPBACK, ASPECT RATIO 4, TAPER RATIO 0.6, AND NACA 65A006 AIRFOIL SECTIONS

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SUMMARY

Rocket-powered flight tests were made from high subsonic to supersonic speeds and at high Reynolds numbers to determine the zero-lift drag of a transonic wing-body and body-alone configuration. The test wing was of 45° sweepback, aspect ratio 4, taper ratio 0.6, and NACA 65A006 airfoil section in the free-stream direction. The body had a fineness ratio of 10 and a frontal area equal to 6.06 percent of the wing-plan-form area.

The test results indicated that at supersonic speeds, the drag coefficient based on total wing area was approximately 0.015 for the body and 0.027 for the body-plus-wing configuration; at subsonic speeds, the drag coefficient was approximately 0.008 for the body and 0.013 for the body-plus-wing configuration. The force-break Mach number was 0.98 for the body and 0.95 for the body-plus-wing configuration. The base contributed very little to the total drag of the test models but indicated a possible interference effect in that the addition of the wing and removal of two stabilizing fins increased the base drag coefficient by 0.002 at a Mach number of 0.95.

INTRODUCTION

As a part of an NACA program of transonic research, the Langley Pilotless Aircraft Research Division is making a series of flight tests at its Wallops Island facility to investigate the aerodynamic characteristics of several rocket-powered wing-body configurations. These tests

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are of a continuous nature from high subsonic to supersonic speeds and at high Reynolds numbers.

This paper presents zero-lift drag data for a body alone and for a wing-body configuration having wings of 45° sweepback on the quarter-chord line, aspect ratio 4, taper ratio 0.6, and an NACA 65A006 airfoil section in the free-stream direction. The body had a fineness ratio 10 with frontal area 6.06 percent of the wing area.

The Mach number range of the tests was from 0.83 to 1.92 and the Reynolds number varied from 6×10^6 to 23×10^6 based on the wing mean aerodynamic chord.

SYMBOLS

C_D	drag coefficient $\left(\frac{\text{Drag}}{qS}\right)$
C_{p_b}	base-pressure coefficient $\left(\frac{p_b - p}{q}\right)$
p_b	pressure acting on base of model, pounds per square foot
p	free-stream static pressure, pounds per square foot
q	dynamic pressure, pounds per square foot $\left(\frac{1}{2}\rho V^2\right)$
ρ	air density, slugs/feet^3
V	velocity, feet per second
M	Mach number $\left(\frac{V}{c}\right)$
c	speed of sound, feet/second
S_w	wing-plan-form area (including area within body), 15.208 square feet
S_B	body frontal area, 0.923 square foot

MODELS AND TESTS

The general arrangements and profile coördinates for the test configuration are shown in figure 1 and table I, and photographs of the test models on the launching stand are given as figure 2. The body was identical for both configurations and had a length of 10.8 feet, diameter of 1.08 feet, and frontal area of 0.923 square foot. The body shape was modified from that of the free-fall bodies, reference 1, by cutting off the pointed stern at the 83.5-percent station. A base-pressure tube was located in the stern end of the body; a detail of its installation is shown in figure 3. The wing had a sweepback of 45° on the quarter-chord line, aspect ratio 4, taper ratio 0.6, and NACA 65A006 airfoil sections parallel to the model center line. The wing-plan-form area was 15.208 square feet and the wing was located such that the one-quarter point of the mean aerodynamic chord fell at the station corresponding to the maximum diameter of the body (6.5 feet rearward of the nose). The wingless configuration was stabilized by four fins and the winged configuration by two fins in the vertical plane and by the wing in the horizontal plane. All fins were of 1.23 square feet exposed area each, having approximately 60° sweepback and mean thickness ratio of 3 percent.

With the exception of the metal fins, all surfaces of both configurations were wood and had a smooth and highly polished lacquered finish.

The wingless and winged configurations were each propelled by a Deacon rocket motor which delivered approximately 6200 pounds of thrust for 3.2 seconds.

Velocity and drag were obtained from the CW Doppler velocimeter described in reference 2 and drag and base pressure were reduced from data telemetered by a two-channel instrumentation unit incorporating a longitudinal accelerometer and pressure cell. Trajectory and atmospheric data were obtained from the NACA modified SCR-584 radar tracking unit and by radiosonde observations.

Total-drag coefficients refer to the measured total drag of the test configurations and base-drag coefficients refer to the drag contribution of the base. The base-drag coefficient is computed as equal to the product of the base-pressure coefficient and the ratio of the base area to wing area (0.015) by assuming that the measured base pressure acts over the entire area of the base.

The error in the results is believed to be within the following limits:

Quantity	Error	
	M = 1.0	M = 1.5
C_D (referred to wing-plan-form area):		
Total	±0.001	±0.001
Base	±0.00038	±0.00015
C_{p_b}	±0.025	±0.010
M	±0.01	±0.01

The variation of Reynolds number with Mach number for the test models is shown in figure 4. The Reynolds number was based on the wing mean aerodynamic chord of 1.99 feet.

RESULTS AND DISCUSSION

Curves of drag coefficient C_D against Mach number M are given in figure 5 for the winged and wingless models. Both telemeter and Doppler drag values are given in figure 5 and also included are the base-drag-coefficient curves which have been taken from the base-pressure coefficients given in figure 6.

The total-drag-coefficient variation for the wingless model showed a subsonic value of 0.008 and rose abruptly at a force-break Mach number of 0.98 to a nearly constant supersonic value of 0.015. The total-drag-coefficient variation for the winged configuration showed a subsonic value of 0.013 and rose abruptly at a force-break Mach number of 0.95 to a rather constant supersonic value of 0.027. It is apparent that the base contributes very little to the total drag of the test configurations at supersonic speeds.

The difference between the winged and the wingless total-drag coefficients represents the wing-plus-interference drag minus a small contribution of two stabilizing fins. The contribution of the two stabilizing fins has been roughly accounted for by adding to the difference between body and wing-body values an estimated C_D increment of 0.001 at subsonic speeds and 0.002 at supersonic speeds. Figure 7 gives the variation of this corrected wing-plus-interference drag coefficient with Mach number. The variation gives a wing-plus-interference drag coefficient of approximately 0.006 at subsonic speeds and 0.013 at supersonic speeds.

Freely-falling-body tests of a configuration having 45° sweptback wings located at two longitudinal stations on the body of reference 1 (from which the present body shape was derived) were reported in reference 3. The reference wings were nontapered, of aspect ratio 4.1, and had NACA 65-series sections of 6.36-percent thickness ratio in the free-stream direction. The wing-plus-interference drag coefficients have been determined from the total-drag-coefficient curves of references 1 and 3 and are compared with the present test results in figure 7. The station of the 0.5-root-chord point of the wings relative to the station of maximum diameter was 1.5 diameters forward and rearward for the reference tests and 0.6 diameter forward for the present tests.

The comparison indicates that the wing-plus-interference drag of the present configuration might be significantly reduced by a rearward shifting of the wing. Evidence of an unfavorable interference effect is indicated below $M = 1$ by the base-drag-coefficient curves in figure 5 wherein the addition of the wing and removal of two fins increased the base-drag coefficient by 0.002 at $M = 0.95$.

Base-pressure coefficients for the body-alone and wing-body configurations are shown over the Mach number range in figure 6. The differences in configuration between the two test models had little effect on the results above a Mach number of 1. Below $M = 1$ however there appears to be a marked quantitative difference due to a configuration change although the qualitative agreement remains good.

Tests of a similar body at low Reynolds numbers but with artificial transition at the nose were reported in reference 4. The base-pressure coefficient was indicated to be -0.035 at $M = 1.5$ which compares favorably with the present results.

Total-drag coefficient, referred to body frontal area, against Mach number is given in figure 8 for the wingless configuration. For comparison, the results of reference 1 are included. When proper allowance is made for the effect of the fins and of the differences in body shape near the tail, reasonable agreement is indicated at supersonic speeds.

CONCLUSIONS

The zero-lift drag of a transonic research model with and without tapered wings sweptback 45° has been measured at supersonic, transonic, and high subsonic speeds and at high Reynolds numbers in flight tests of rocket-powered models. Within the limit of the investigation the results indicated the following:

1. The drag coefficient at supersonic speeds was approximately 0.015 for the body and 0.027 for the body-plus-wing configuration.

2. The drag coefficient at subsonic speeds was approximately 0.008 for the body and 0.013 for the body-plus-wing configuration.

3. The force-break Mach number was 0.98 for the body and 0.95 for the body-plus-wing configuration.

4. The base contributed very little to the total drag of the test models, but the base-pressure data indicated a possible interference effect in that the addition of the wing and removal of two stabilizing fins increased the base-drag coefficient by 0.002 at a Mach number of 0.95.

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REFERENCES

1. Thompson, Jim Rogers, and Mathews, Charles W.: Total Drag of a Body of Fineness Ratio 12 and Its Stabilizing Tail Surfaces Measured during Free Fall at Transonic Speeds. NACA CB L6D08, 1946.

2. Alexander, Sidney R., and Nelson, Robert L.: Flight Tests to Determine the Effect of Taper on the Zero-Lift Drag of Wings at Low Supersonic Speeds. NACA RM L7E26, 1947.

3. Mathews, Charles W., and Thompson, Jim Rogers: Comparison of the Transonic Drag Characteristics of Two Wing-Body Combinations Differing Only in the Location of the 45° Sweptback Wing. NACA RM L7I01, 1947.

4. Chapman, Dean R., and Perkins, Edward W.: Experimental Investigation of the Effects of Viscosity on the Drag of Bodies of Revolution at a Mach Number of 1.5. NACA RM A7A31a, 1947.

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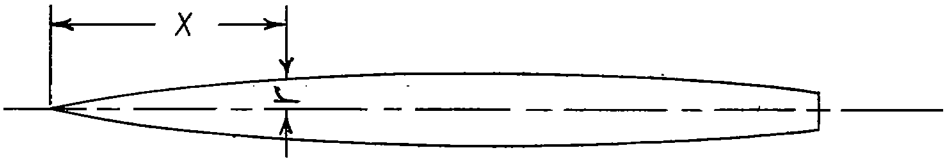
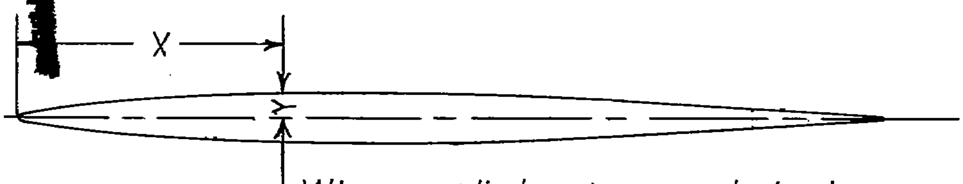
TABLE I

BODY AND WING COORDINATES FOR TEST MODELS



Body coordinates in inches

Body coordinates 130-inch transonic model			
X	r	X	r
0.000	0.000	54.600	6.135
0.780	0.360	62.400	6.339
1.170	0.465	70.200	6.462
1.950	0.668	78.000	6.500
3.900	1.126	85.800	6.442
7.800	1.880	93.600	6.276
11.700	2.517	101.400	5.993
15.600	3.075	109.200	5.556
23.400	4.046	117.000	4.880
31.200	4.820	124.800	3.940
39.000	5.405	130.000	3.231
46.800	5.836		
Nose radius = .078 inch			



Wing coordinates in percent chord

Wing coordinates NACA 65A006			
X	Y	X	Y
0.00	0.000	40.00	2.996
0.50	0.464	45.00	2.992
0.75	0.563	50.00	2.925
1.25	0.718	55.00	2.793
2.50	0.981	60.00	2.602
5.00	1.313	65.00	2.364
7.50	1.591	70.00	2.087
10.00	1.824	75.00	1.775
15.00	2.194	80.00	1.437
20.00	2.474	85.00	1.083
25.00	2.687	90.00	0.727
30.00	2.842	95.00	0.370
35.00	2.945	100.00	0.013
L.E. radius = .229 % c		T.E. radius = .014 % c	

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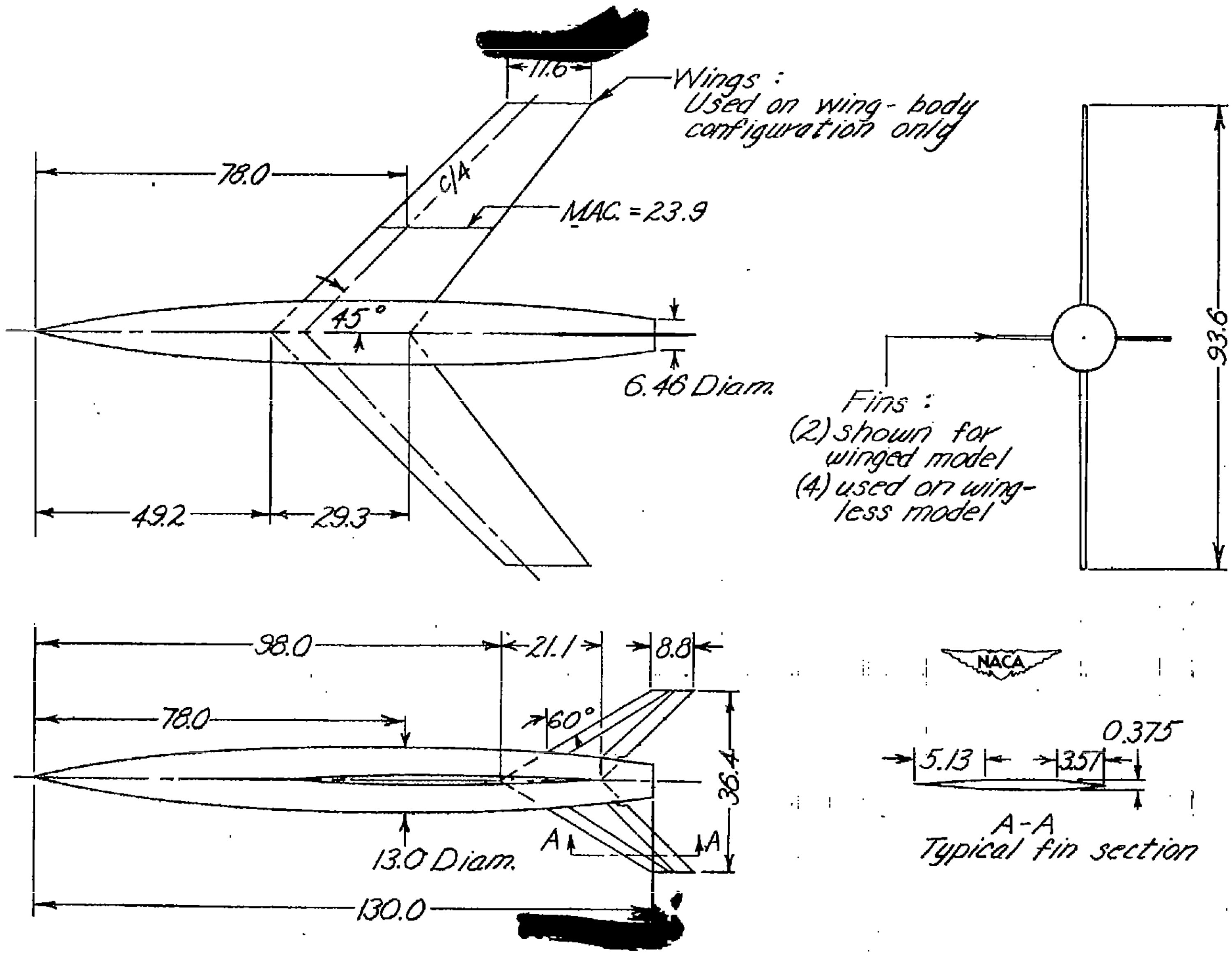

Figure 1.– General arrangement of test model. Wing-body configuration shown. Body-alone configuration identical except as noted.

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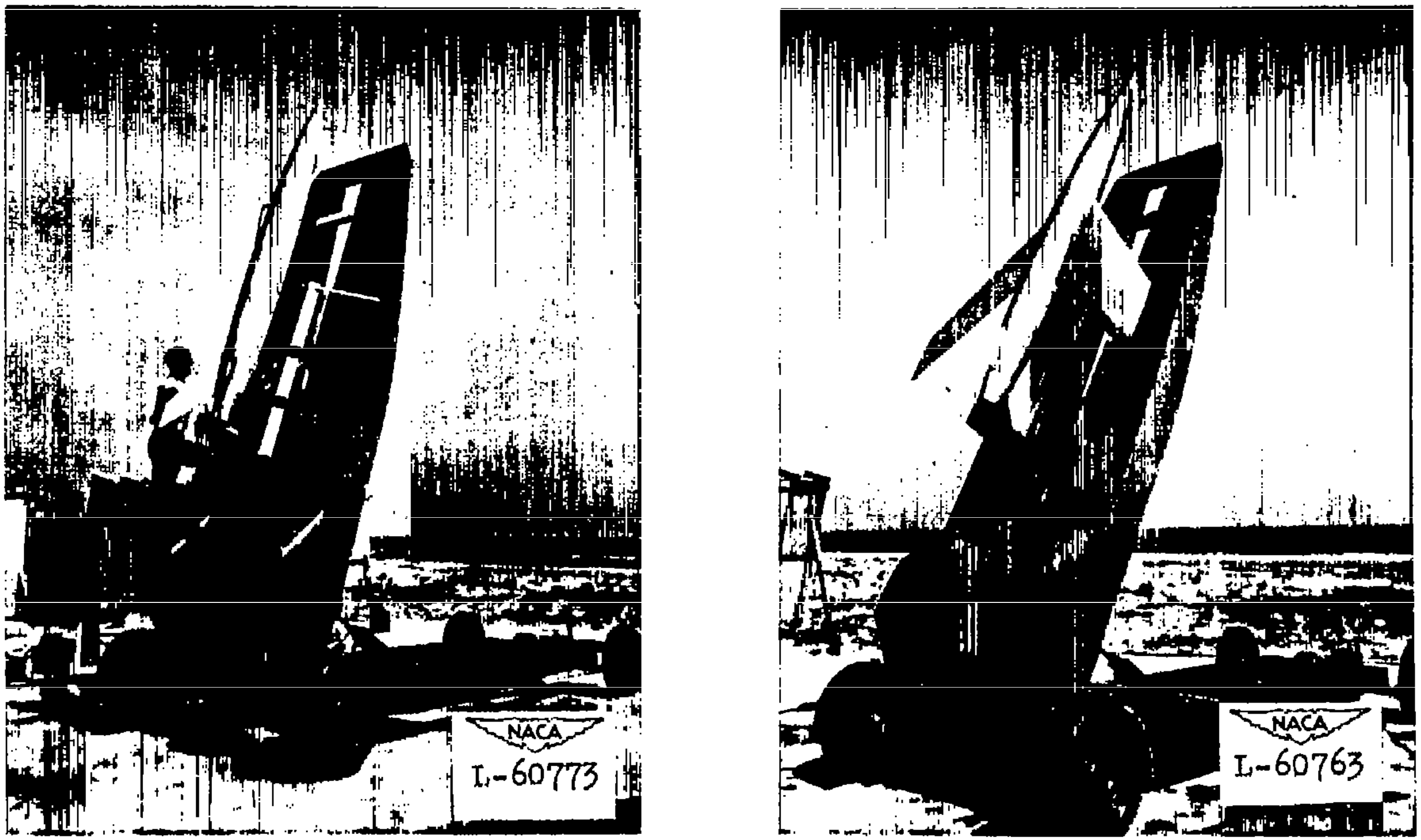

(a) Body alone.

(b) Wing-body configuration.

Figure 2.– Photographs of models in launching position.

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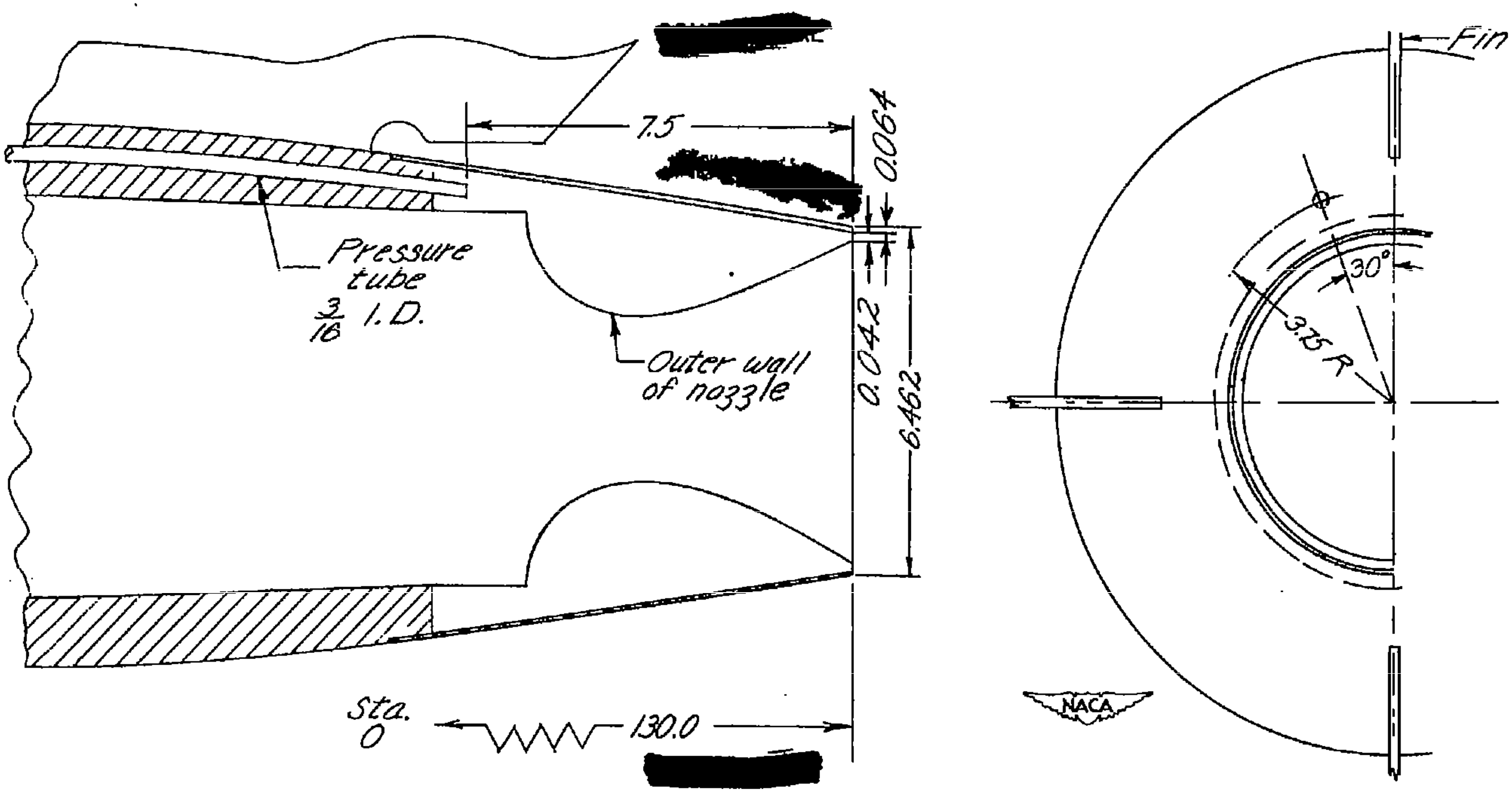

Figure 3.– Detail of base-pressure-tube installation.

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[redacted]

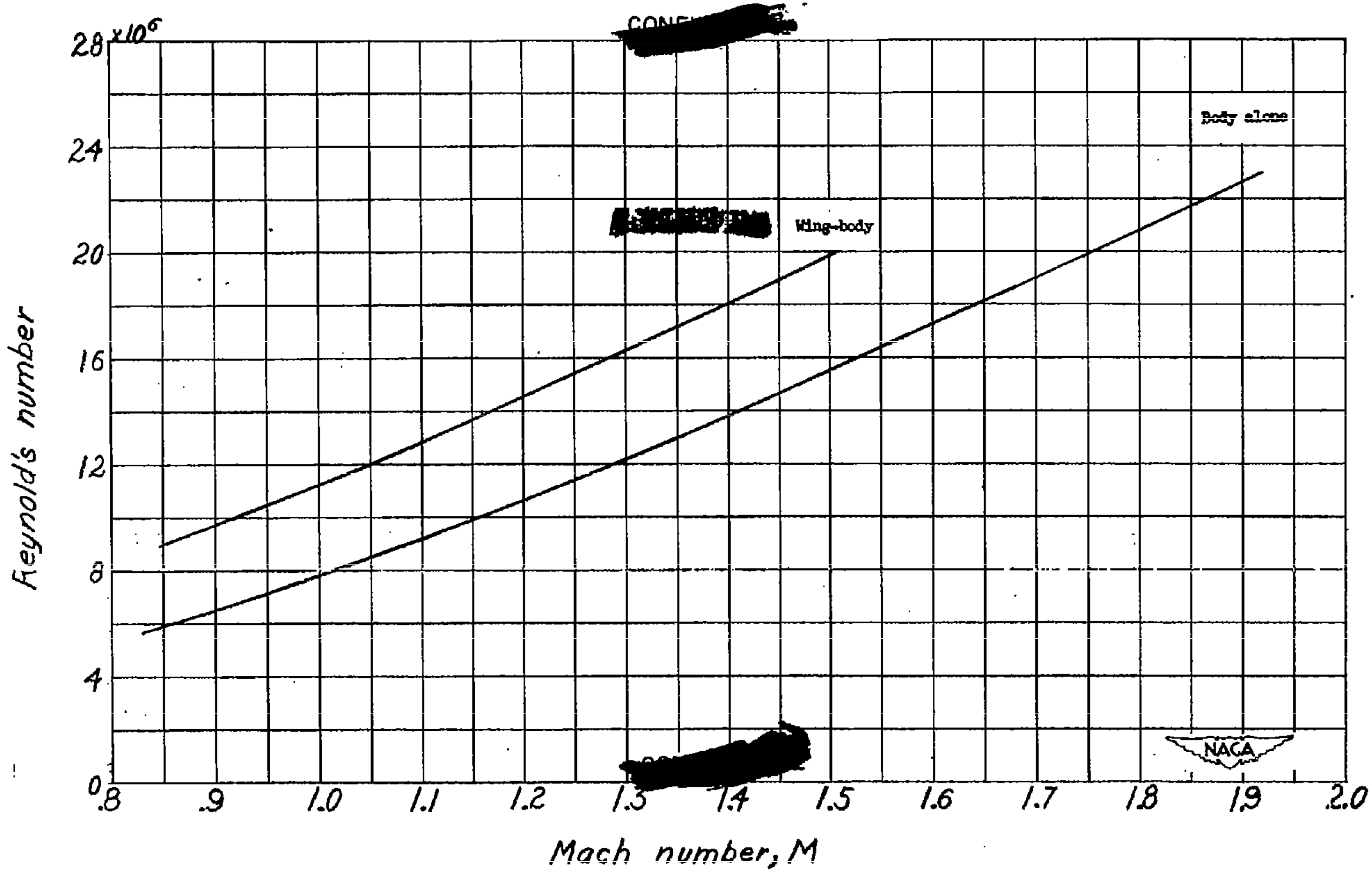

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Figure 4.– Variation of Reynolds number with Mach number for test models. Reynolds numbers based on wing mean aerodynamic chord of 1.99 feet.

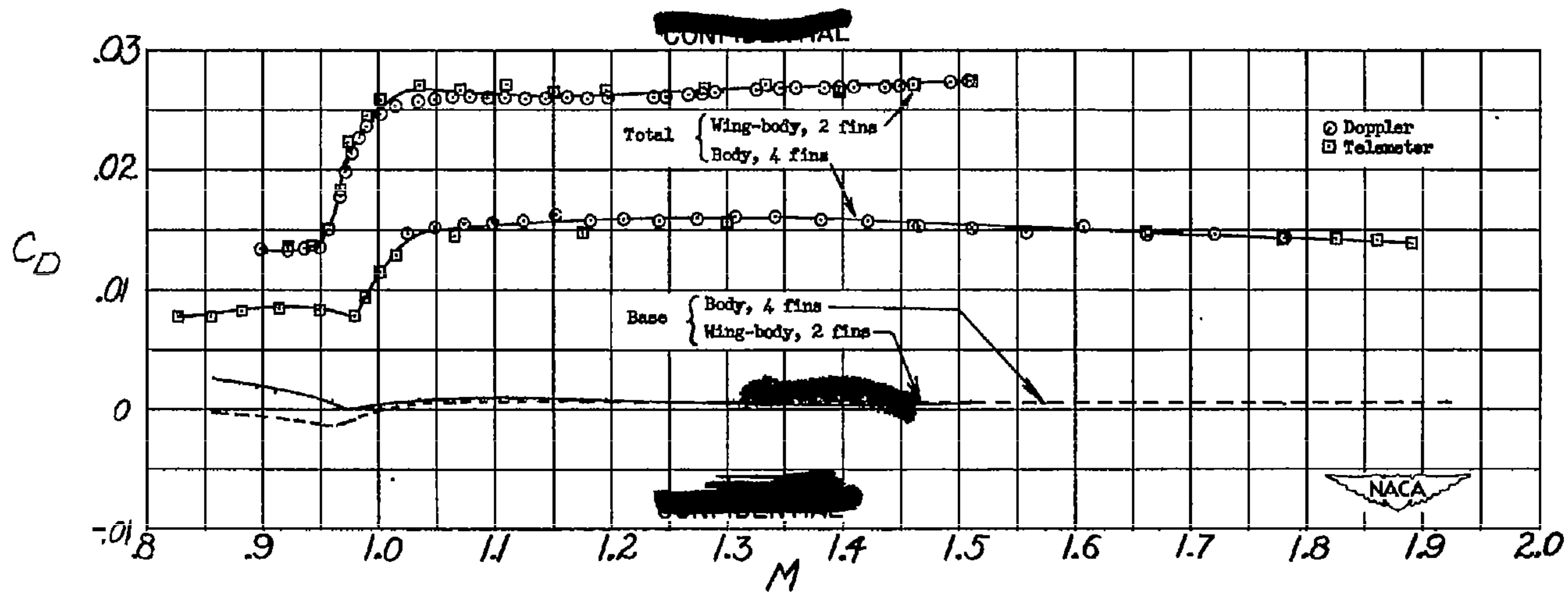

Figure 5.– Variation of total- and base-drag coefficients with Mach number for the test models. C_D referr[redacted]lan-form area.

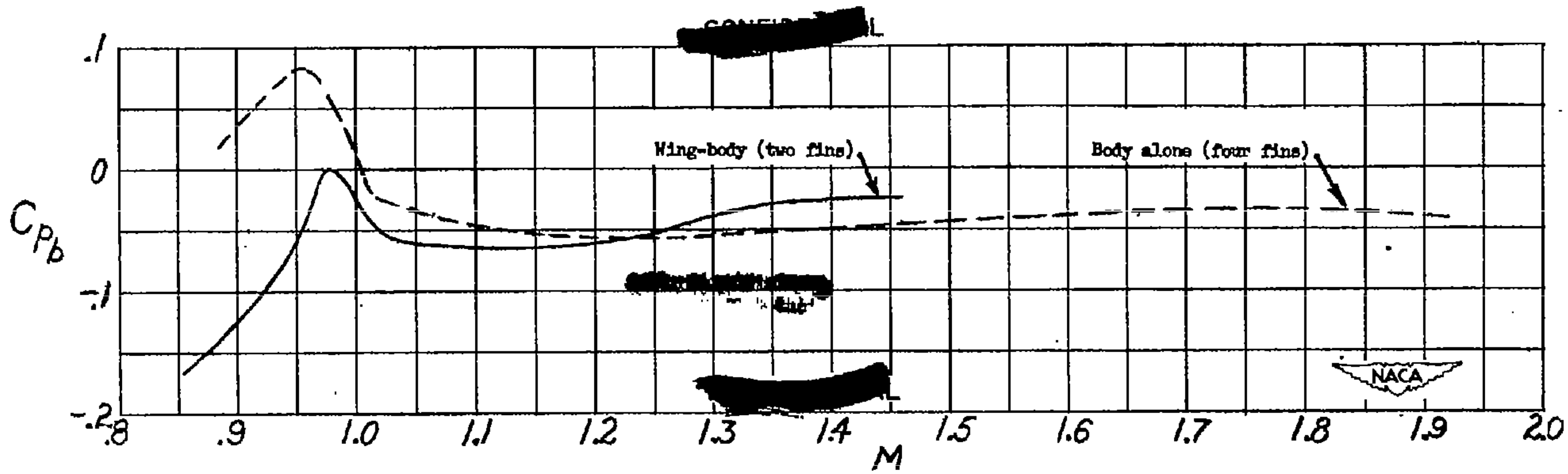

Figure 6.— Variation of base-pressure coefficient with Mach number for the test models.

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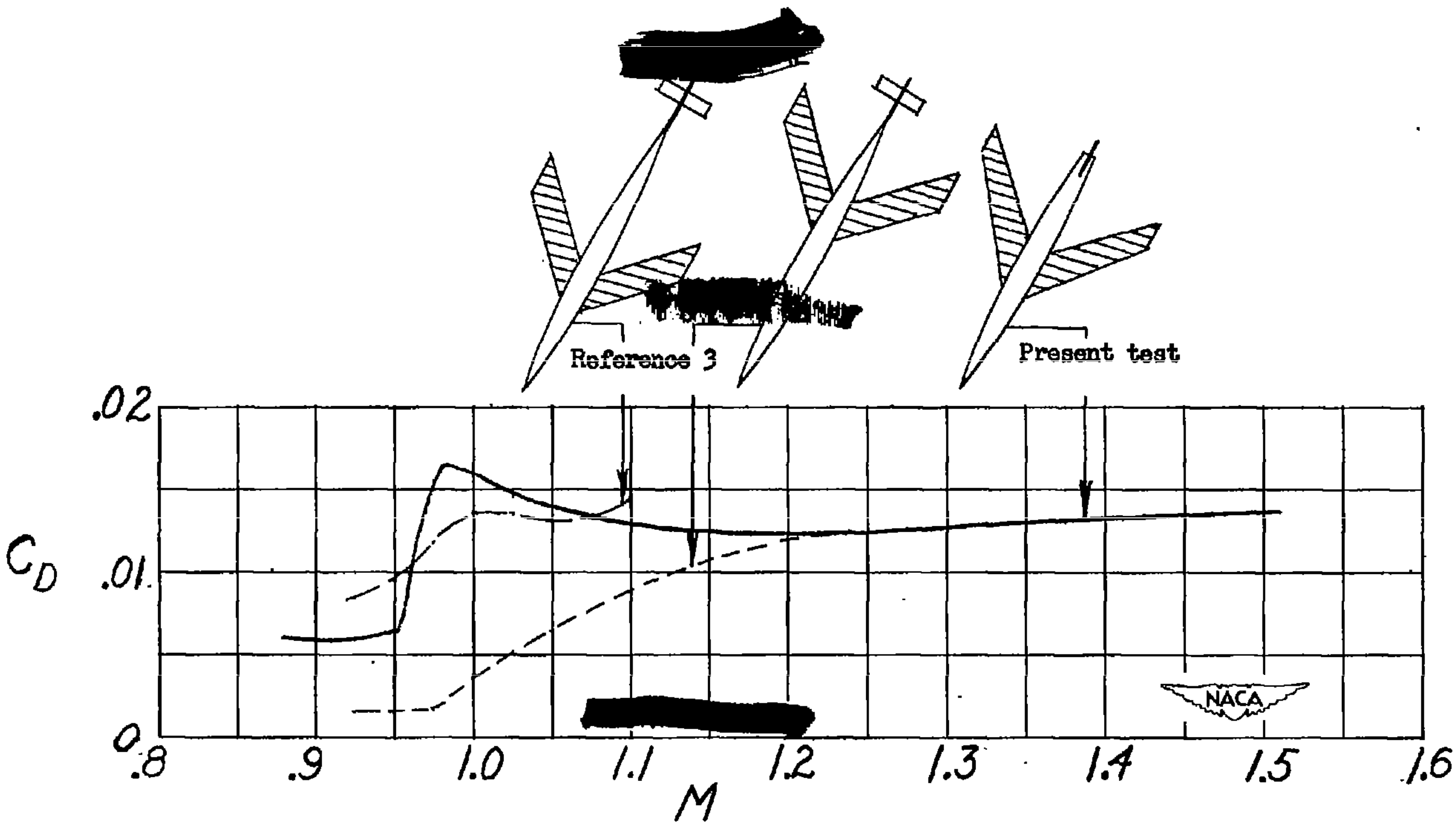

Figure 7.– Variation of wing–plus–interfer[redacted] drag coefficient with Mach number. C_D based on wing-[redacted]rea.

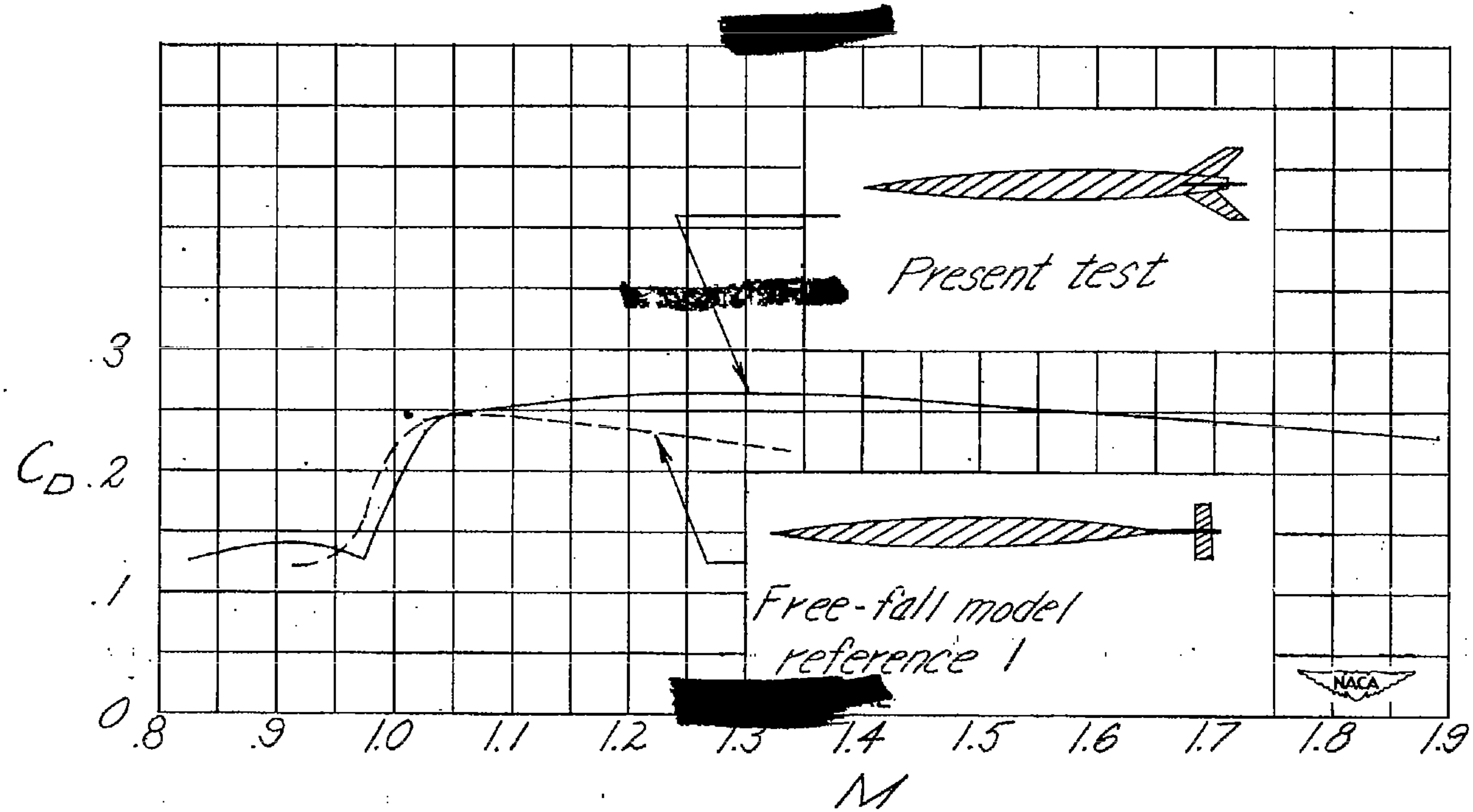

Figure 8.— Variation of total-drag coefficient with Mach number for wingless configuration and free-fall model. [redacted] based on body frontal area.

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